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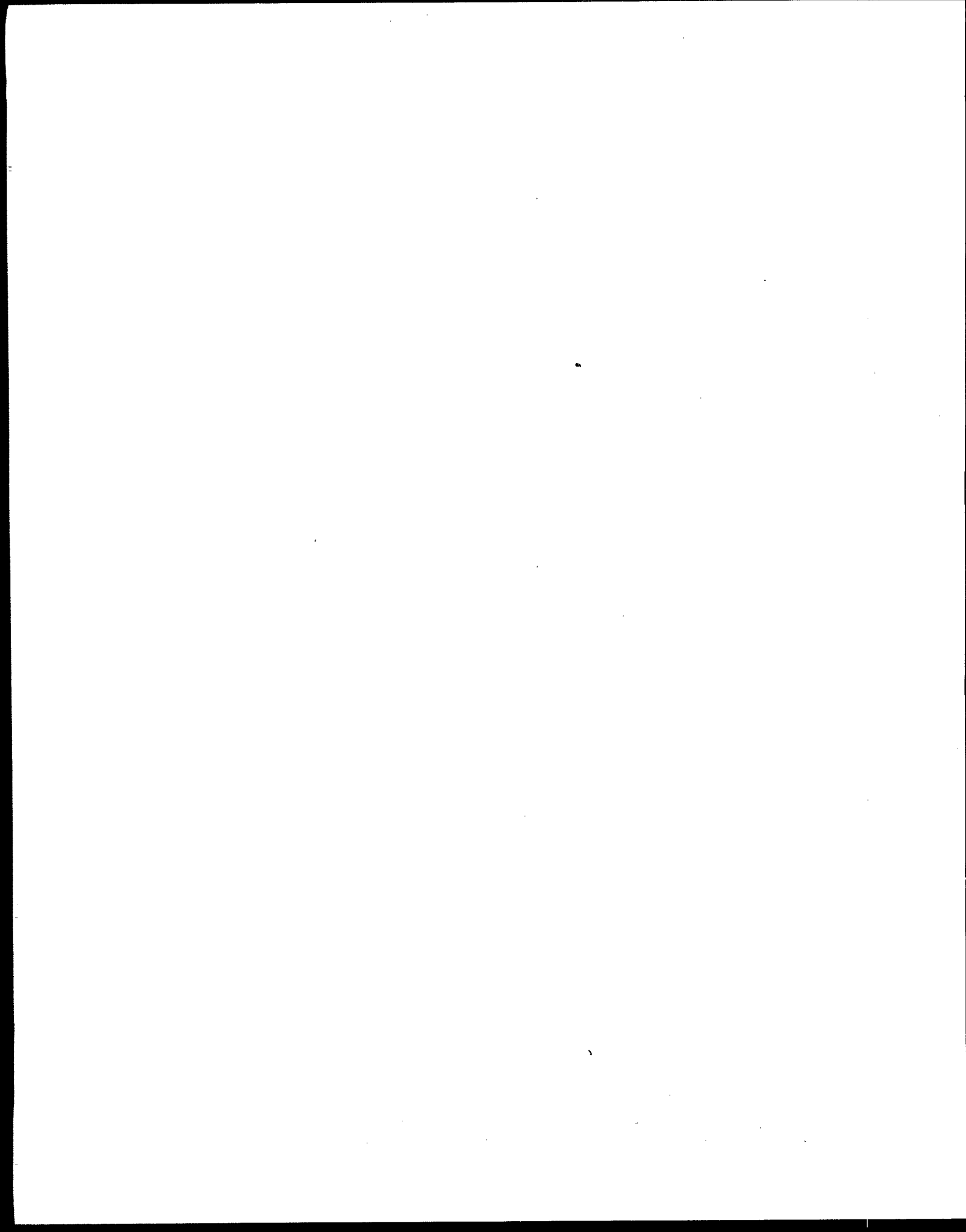
NATO/CCMS Pilot Study

Evaluation of Demonstrated and
Emerging Technologies for the
Treatment and Clean Up of
Contaminated Land and
Groundwater

PHASE II OVERVIEW REPORT

Number 219

NORTH ATLANTIC TREATY ORGANIZATION



**Overview Report
NATO/CCMS Pilot Study**

**Evaluation of Demonstrated and Emerging
Technologies for the Treatment and Clean Up
of Contaminated Land and Groundwater
(Phase II)**

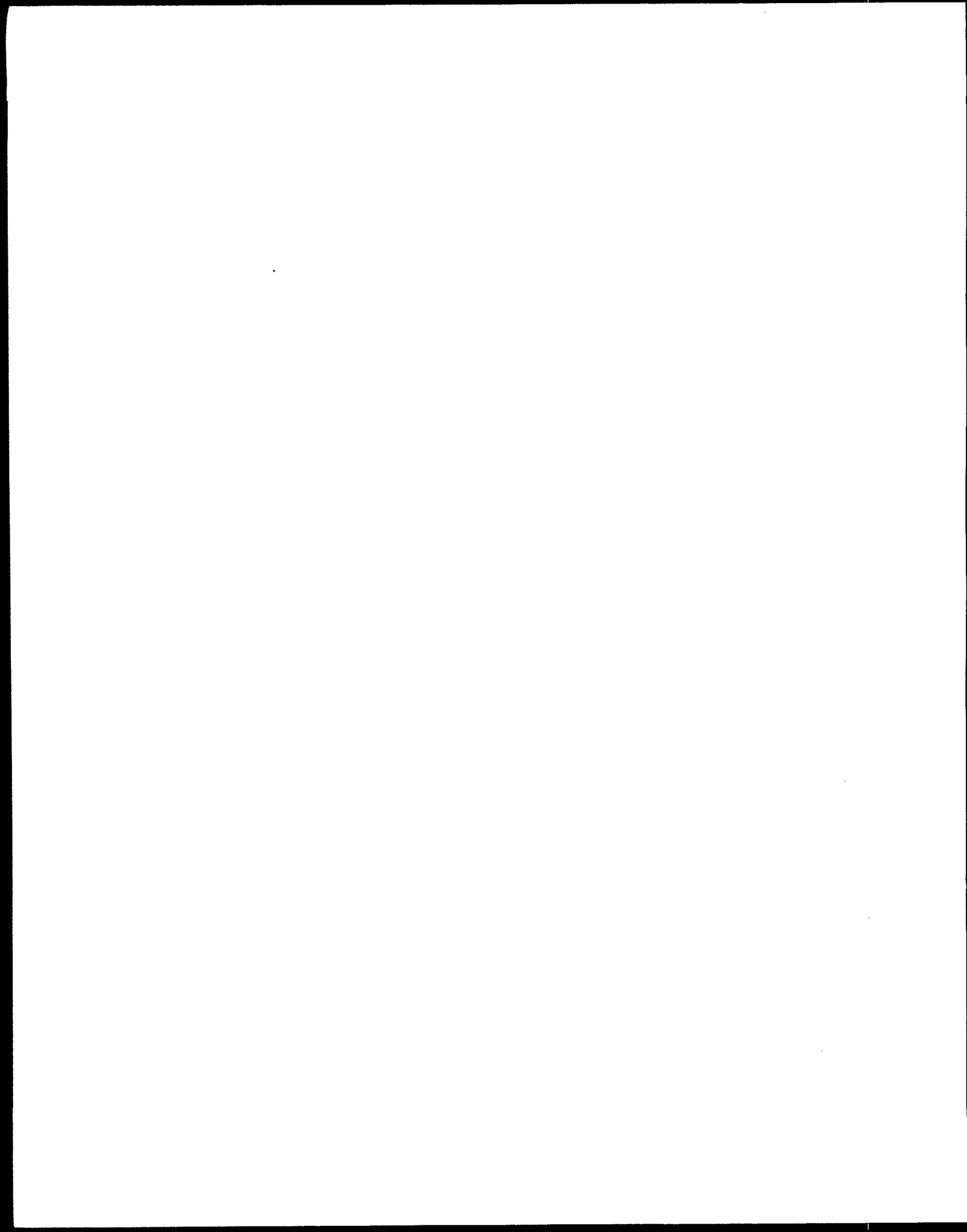
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NOTICE

This report was prepared under the auspices of the North Atlantic Treaty Organization's Committee on the Challenges of Modern Society (NATO/CCMS) as a service to the technical community by the United States Environmental Protection Agency (U.S. EPA). The document was funded by U.S. EPA's Technology Innovation Office under the direction of Michael Kosakowski (Work Assignment Manager). Michael A. Smith of Berkhamsted, U.K., was the principal editor for the Pilot Study reports and the author of this Overview Report. The Overview Report was edited and produced by Environmental Management Support, Inc., of Silver Spring, Maryland, under U.S. EPA contract 68-W6-0014. Mention of trade names or specific applications does not imply endorsement or acceptance by U.S. EPA.

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1. INTRODUCTION

This report provides an overview of the Phase II Pilot Study on the Evaluation of Demonstrated and Emerging Technologies for Treatment and Clean Up of Contaminated Land and Groundwater. It also contains the key conclusions of the Pilot Study and recommendations for further action. A detailed account of the Phase II Pilot Study is provided in the Final Report (1).

The Phase II Pilot Study was proposed to NATO by the United States Environmental Protection Agency (U.S. EPA) at the Committee on the Challenges of Modern Society's (CCMS) plenary session in April 1992. Member countries voted on and accepted the proposal at the same meeting.

The study was conducted under the joint leadership of the United States, the Federal Republic of Germany, and the Netherlands. It was co-chaired by Mr. Stephen James and Dr. Walter Kovalick, Jr., of U.S. EPA. Dr. Deniz Beten, Director of CCMS Programs, provided liaison with the NATO/CCMS secretariat. Additional information on CCMS and the Pilot Studies may be obtained from the Country Representatives listed at the back of this document.

The Pilot Study Group held a total of seven meetings during the course of the study. During these meetings, countries submitted candidate projects that were discussed and voted on for inclusion in the study based on criteria agreed upon by the participating countries. In-depth interim and final report presentations on the implementation and results of these projects were made during the international meetings and summarized in meeting proceedings. Australia, Austria, Canada, the Czech Republic, Denmark, France, Germany, Hungary, the Netherlands, Norway, Sweden, Switzerland, Turkey, the United Kingdom, and the United States provided projects to the study. In addition, Belgium, Hong Kong, Italy, New Zealand, Poland, Portugal, Romania, Slovenia, and the Slovak Republic were represented at one or more meetings by a government representative, a CCMS Fellow, or an individual expert.

Each project was planned and executed by the responsible organization, with project funding from the various government and non-government organizations involved. The costs of participating in international meetings and preparing project reports were generally met by these organizations concerned, which in many cases were private companies.

Each international conference included host country presentations and a *tour de table*, during which member countries discussed developments in national legislation, regulations, and research and development programs. In addition, recognized experts in diverse technical fields gave invited papers related to the challenges of soil and groundwater remediation, and CCMS Fellows provided presentations and written reports on their work. These reports from Fellows were published as part of the proceedings of the international meetings and are contained in Appendix V of the Final Report.

The Final Report was prepared by a voluntary team drawn from a number of countries. The Pilot Study Directors acknowledge the efforts of the members of the team without whose contributions it would not have been possible to produce the report. The Final Report was published by U.S. EPA. Contributions towards the direct costs of preparing the Final Report have also been made by Denmark, Germany, Norway, Sweden, and the United Kingdom.

The various Pilot Study activities resulted in extensive transfer of study findings to potential users of new remediation technologies and to a wider technical and administrative audience. They also increased the exchange of ideas on technology needs and fostered greater contact among experts and decision-makers within both member and non-member countries.

2. BACKGROUND AND PURPOSE

The problem of land and groundwater contamination from improper handling and disposal of hazardous materials and wastes is faced by all countries. Many countries have committed resources to developing advanced, innovative remediation technologies and to evaluating them under field conditions. The ongoing challenge is how to maximize the value of these technology demonstrations and effectively transfer the technologies both within and between countries. In addition, there has been an increasing recognition of the need for approaches not dependent on advanced technologies and for technologies that can be cost-effectively employed in the socioeconomic circumstances of Eastern and Central Europe and developing countries.

The purpose of this NATO/CCMS pilot study was to identify, discuss, and review innovative, emerging, and alternative technologies, and to transfer technical performance and economic information to potential users of these technologies. A specific objective of the study was to identify "lessons learned" from the technology demonstrations—both the successes and those that illustrated technology failures or limitations. The latter type of information is rarely presented in conferences or discussed in the technical literature, but is very important for making informed decisions involving critical time and monetary requirements. It is also useful for defining priorities in research and development programs.

3. RELATIONSHIP WITH OTHER CCMS PROGRAMS

3.1 The CCMS Fellowship Program

The CCMS Fellowship Program made an important contribution to the success of the Phase II Pilot Study, as it did to the two earlier Pilot Studies on the remediation of contaminated soil and groundwater. It facilitated participation of several experts, including experts from countries such as Portugal, that would otherwise not have had a presence in the Pilot Study. The participation of these experts enabled a wider range of topics to be covered.

Ten NATO Fellowships were awarded under this Pilot Study. Nine Fellows conducted associated studies and submitted project reports to the Pilot Study under guidance of the Pilot Study Directors. One edited the Final Report and contributed to the content of the report; two other Fellows also contributed to the preparation of the report. All of the Fellows attended one or more meetings of the Pilot Study Group and played an active part in the discussions.

The Fellows came from private, university, and governmental organizations in the Federal Republic of Germany, the Netherlands, Portugal, Turkey, the United Kingdom, and the United States. Their activities covered a range of topics related to the Pilot Study, including an examination of the national approach to such problems as costs and economics, quality management, innovative approaches to large-scale remediation projects, and assessment of the performance of *in situ* treatment methods.

3.2 CCMS Study Visit Program

Participation by a number of individuals, including expert speakers, was made possible by the provision of travel funds through the CCMS Study Visit Program.

4. ACCOMPLISHMENTS

The Pilot Study Group examined 52 different remediation technology projects from 14 countries during the five-year program. The projects encompassed *in situ* and *ex situ* biological, physical-chemical, and

thermal treatment technologies. Many of the projects involved two or more technologies, either in integrated treatment systems or in parallel treatment. The reports on these projects revealed an ongoing evolution of innovative and advanced technologies. The Pilot Study is believed to have been instrumental in facilitating this development.

Non-member countries, including members of the North Atlantic Cooperation Council (NACC) took increasing interest in and participated in the Phase II Pilot Study. For example:

- The first Pilot Study meeting was held in Budapest in 1992—the first CCMS meeting to be held in a NACC country. A number of the participants presented papers at an international environmental meeting held the previous week.
- The third meeting was held in Adelaide, Australia, in February 1995 and was co-hosted by the Commonwealth EPA.
- Projects were contributed by a number of non-member countries including, Australia, the Czech Republic, Hungary, Sweden, and Switzerland.

The Pilot Study was designed to provide participants with a broader view of the research strategies of other countries to help them focus their own research strategy. Technology transfer from the Pilot Study was promoted by circulating meeting reports, involving members in conferences and symposia, and publishing papers in professional journals. Some examples of this activity are listed below:

- The proceedings of the Pilot Study meetings were provided to country representatives (nominated by their respective countries for participation in the meetings) to duplicate and distribute within their countries, as needed.
- In 1995, U.S. EPA published an Interim Status Report (2) that was distributed to all participating countries and others worldwide.
- The German Federal Ministry of Environment, Nature Protection, and Reactor Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) commissioned one CCMS Fellow to prepare a report of the meeting held in Berlin in 1996 and a review of research needs (3). This report was circulated to country representatives.
- During the Pilot Study meetings, participants visited soil treatment facilities, ongoing site cleanup, and research institutions. These activities stimulated the participation of private companies in the Pilot Study and enlarged the network of international experts and increased their interactions.
- The Pilot Study Director and Co-Directors provided annual reports to NATO/CCMS.
- The Co-Directors and other members of the Pilot Study served on numerous science advisory committees and presented invited papers at national and international technology conferences and symposia at national conferences in Australia, the Netherlands, Canada, Luxembourg, the United Kingdom, and the United States. A special session based on the Pilot Study formed part of the Netherlands Research Organization (TNO) international conference on contaminated soil, held in Maastricht in 1995.
- A paper describing the current Pilot Study and the achievements of earlier studies on contaminated land and groundwater (4) was presented at an International Symposium on the Rehabilitation of

Military Sites and Demilitarization of Explosive Ordnance, held in Luxembourg 1994 and co-sponsored by NATO, the World Health Organization, and the Grand Duchy of Luxembourg.

- In the United Kingdom, a number of related reports were prepared for the U.K. Department of the Environment. One of these formed the basis for a wider publication.

In addition to the technical issues that were the focus of this Pilot Study, each meeting started with a *tour de table*, during which each country discussed developments in national legislation, regulations, technical criteria, and guidelines (5). Understanding differences in policy and management strategies in other countries has been helpful to study members for discussions when they returned to their countries.

Close liaison was maintained throughout the study with other international groups dealing with the problems of contaminated land including:

- the CCMS Pilot Study on the Environmental Aspects of Reusing Military Lands;
- the “*Ad hoc* International Working Group” on Contaminated Land, which grew out of discussions among country representatives attending the NATO/CCMS meetings. The Working Group exists to provide a forum—open to any country—in which the issues and problems of contaminated land and groundwater can be discussed at a national level and information can be freely exchanged to the benefit of all participants;
- the Common Forum on Contaminated Land in the European Union, which also began through the NATO/CCMS meetings;
- CARACAS* (the European Union’s [EU] Concerted Action on Risk Assessment for Contaminated Sites);
- NICOLE* (the EU’s Concerted Action Network for Industrially Contaminated Land in Europe);
- the International Organization for Standardization’s (ISO) Technical Committee TC190: Soil Quality, which is preparing international standards for soil and site assessment, including chemical, biological, and physical testing methods; and
- the German-United States Bilateral Agreement, the goals of which are to:
 - facilitate an understanding of each country’s approach to the remediation of contaminated sites;
 - demonstrate innovative remedial technologies;
 - compare quality assurance programs; and
 - facilitate technology transfer.

* CARACAS (coordinated by the German Umweltbundesamt) and NICOLE are both funded by the European Commission’s Directorate General XII under the Environment and Climate Research and Development Program.

5. TECHNICAL OVERVIEW

5.1 Introduction

There were 52 active projects in the Pilot Study. Summary information on each project is provided in Appendix IV (Volume 2 of the Final Report). The project summaries provide a technical abstract, which summarizes the project's progress and results, but is not a critical review of the project. The summaries also provide the name of a technical contact for further information.

While the objective of the Pilot Study was to evaluate applications of particular technologies, a large proportion of the projects involved more than one technology. Some involved the use of integrated treatment systems combining more than one technology, and others involved the application of more than one technology to deal with separate aspects of site contamination. Other projects concerned theoretical studies, strategic scientific studies, or large-scale remediation projects for which the remediation strategy had yet to be developed.

Because the projects are classified below in a variety of ways, they may be counted two or three times, and not all projects may be included in each analysis. Furthermore, the categorization of projects is a matter of judgment, and alternative categorizations may be possible. The projects are classified in the following sections as follows:

- by the development status of the technology (Section 5.2);
- whether they are *in situ* or *ex situ* technologies, or a combination of both (Section 5.3);
- by the type of technology used (Section 5.4);
- by the contaminants treated (Section 5.5); and
- whether they involve a single technology, mixed technologies, or integrated treatment systems.

5.2 Development Status

Forty-nine of the 52 active projects were technology-based. The Pilot Study accepted technical projects in two areas of development: "emerging" and "demonstration." For the purposes of the Pilot Study, an emerging technology is defined as being at bench- or pilot-scale, while a demonstrated technology is one implemented at field- or full-scale. Demonstrated technologies are usually at or near to commercial application. There was almost an even split of projects within the Pilot Study examining emerging and demonstrated technologies.

5.3 *In Situ* vs. *Ex Situ* Technologies

There were 18 projects using *in situ* technologies: 26 projects using *ex situ* technologies, six projects using both *in situ* and *ex situ* technologies, and two projects (Projects 22 and 56) for which the remediation strategy had yet to be decided.

5.4 Technology Types

For the purposes of the Final Report the technologies described in each technical project were broadly classified as one of five types: biological, chemical, physical-chemical, stabilization/solidification, or

thermal. The additional categories of "integrated" and "mixed" are used to describe combinations of technologies used as part of an overall remediation strategy. "Integrated" refers to approaches where two or more technologies are used simultaneously or in series to treat a specific site problem. "Mixed" projects involve two or more technologies used to treat different contaminated areas or media as part of an overall remedial strategy.

The classification of projects was as follows (Note that some projects were counted twice.):

Technology Type	Number of Projects	Examples of Technologies
Biological	24	bioventing, biopiles, slurry reactors, white rot fungi
Physical-Chemical	29	soil vapor extraction, soil washing, solvent extraction, ultraviolet treatment
Chemical	4	photochemical oxidation, ozone treatment, sorption, leaching
Thermal	5	thermal desorption, incineration, thermal vitrification
Stabilization/Solidification	2	chemical fixation, grouting
Other	4	site characterizations, free-product recovery

There were 23 projects that relied upon a single technology, 19 that used integrated technologies, seven mixed technologies, and three that did not involve treatment. Typical combinations were soil vapor extraction with *in situ* biotreatment, soil washing followed by biotreatment, and soil washing followed by thermal treatment.

5.5 Contaminants Treated

Forty of the 52 projects were concerned only with the treatment of organic contaminants, including polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and BTEX compounds (benzene, toluene, ethylbenzene, and xylenes). Six projects dealt exclusively with metals, and six dealt with both inorganic and organic contaminants. One project focused on remediation of inorganic sulfates and cyanides.

6. THE PHASE III PILOT STUDY

The country representatives and other participants in the Pilot Study agreed on the merit of a Phase III Pilot Study—both for those countries having established programs to address contaminated land and for those who have more recently begun to address contamination problems, such as countries in Central and Eastern Europe. In addition, developing countries might benefit by avoiding the environmental degradation that accompanied the industrialization of Europe and North America. Particular needs identified included more extensive, cheaper, and sustainable treatment technologies, and studies of containment methods.

The United States formally proposed a follow-up Pilot Study at the CCMS Plenary Meeting held in April 1997. The proposal was accepted, and Germany and The Netherlands agreed to participate as co-pilot

countries. The new Pilot Study was welcomed by Cooperation Partners at the subsequent "Continuation of the Plenary Meeting." The first meeting of the new Pilot Study was held in Vienna, Austria, in February 1998. Seven projects initiated during this Phase II study will be continued during the Phase III study.

7. CONCLUSIONS

This Phase II Pilot Study again demonstrated the benefits of exchanging technical and economic information on contaminated land and groundwater remediation technologies. The full conclusions of the Pilot Study are presented in the Final Report, together with supporting statements. The conclusions are based on the deliberations of the Pilot Study Group, case studies, expert speaker presentations, special studies carried out by Fellows of the Pilot Study, and the experience and expertise of the individual chapter authors. The conclusions are of four types:

- general conclusions arising from the Pilot Study;
- general conclusions about remediation and technology transfer;
- conclusions relating to individual chapters in the report; and
- research needs.

Seven of the conclusions listed in the Final Report are regarded as particularly important and are listed below:

1. Remediation strategies in a number of countries are moving from technology-intensive treatment processes to increasing use of land use management and extensive approaches such as natural attenuation.
2. The intended future use of a site is increasingly a determining factor when setting clean-up objectives and selecting a remediation strategy.
3. Integrated treatment systems are frequently needed for site remediation.
4. Energy efficiency practices influence plant design resulting in varying processing costs between countries. This may make cost comparisons between countries difficult and lead to the choice of different technologies to address similar problems.
5. All remediation activities require proper operation and management.
6. Independent evaluation and verification of technologies and uniform data collection are needed for effective technology transfer.
7. Scientific understanding of processes is essential to avoid forming harmful end-products and byproducts, ensure process optimization, avoid unwanted transfer of contaminants to other media, and understand the limits of technical performance.

8. RECOMMENDATIONS

- 1) *The CCMS is invited by the Pilot Study Directors to commend this Phase II Pilot Study Final Report to the NATO Council for approval.*

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